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EXPOSURE TO ENVIRONMENTAL TOBACCO SMOKE IN THE NON INDUSTRIAL WORKPLACE UNDER DIFFERENT CONDITIONS OF VENTILATION AND SMOKING REGULATION

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INTRODUCTION

This report presents the results of three field studies examining levels of environmental tobacco smoke (ETS) in office buildings under conditions of normal occupancy, smoking and ventilation. Nicotine, Respirable Suspended Particles (RSP), Carbon Monoxide (CO) and Carbon Dioxide (CO_2) were measured as markers of ETS. One or more of these substances have frequently been measured in investigations of smoking and nonsmoking offices.(1,2) Of these four substances, only nicotine is uniquely related to the combustion of tobacco. RSP concentrations vary with different types of human activities found in office buildings. CO and CO_2 are byproducts of tobacco combustion which also have multiple other sources. A main source of CO in office buildings is the infiltration of automobile exhaust. The primary sources of CO_2 are the outdoor air and the exhaled breath of occupants.

The field studies were designed to evaluate two questions:

1. What is the contribution of smoking to indoor ETS concentrations (as measured by nicotine, RSP, CO_2 and CO)?
2. How does the restriction of smoking to specially designated, but not separately ventilated, areas effect the levels of ETS in nonsmoking office spaces?

SAMPLING AND ANALYTICAL METHODS

Nicotine

Indoor nicotine samples were collected using a air sampling pump housed inside a briefcase. Samples were collected by pumping air

at 1 liter per minute through sorbent tubes containing XAD-4 resin, a styrene divinylbenzene copolymer. The sampling techniques collects gaseous phase nicotine, rather than particulate phase. Collected samples were analyzed with a gas chromatograph equipped with a nitrogen-phosphorous detector, using a procedure based on a standardized NIOSH analytical method.(3)

RSP, CO and CO2

Instantaneous measurements for RSP, CO and CO_2 were taken during the nicotine sampling periods. Measurements of each substance were taken at the start and completion of each nicotine sampling period, and at one hour intervals throughout the intervening time. The data were averaged to provide a representative value for each sampling period.

RSP concentrations were measured with a Sibata P-5H Digital Dust Indicator, which determines RSP concentrations as a function of the intensity of scattered light as respirable particles (< 3.5 μm) are drawn through a sensing chamber. The instrument had been calibrated to ETS particles through side by side comparison with gravimetric sampling.

CO concentrations were measured using a direct reading electrochemical analyzer (NOVA 310L), CO_2 was measured using extra low range colorimetric detector tubes.

Other Observations

During each field investigation, observations of occupant behavior were also made. In Studies One and Three, the number of occupants and the number of cigarettes smoked in each predefined observation area were recorded for the entire sampling period. In Study Two, the number of cigarettes being smoking at the time of the instantaneous measurements of RSP, CO and CO_2 were observed, and a mean value calculated.

RESULTS

Study 1

The first field study was undertaken in an 14-storey office building. Measurements of nicotine, CO and CO_2 were taken on the 7th and 11th floors of the building. (RSP measurements were also analyzed, but not recorded due to instrument failure.) Smoking was restricted to a 22.5 m^2 lounge on the 7th floor, without separate ventilation. No smoking was allowed elsewhere on the 7th floor.

On the 11th floor, smoking was permitted without restriction. The layout and design of the two floors were similar with an open plan office area of 780 m^2 surrounding a central core, containing mechanical rooms and service shafts.

Each floor of the building was independently ventilated. Outside air was ducted from a rooftop intake to a mechanical room on each floor. An air handling unit in the mechanical room mixed outside air with return air from the office space, then filtered and heated or cooled the mixed air before suppling it to the office space. Supply air was ducted through the suspended ceiling to rectangular ceiling diffusers. The suspended ceiling was also used as the return air plenum. On the days of sampling, the system was introducing 15-20% outside air to the space. Therefore, a proportion of the air exhausted from the smoking lounge was recirculated into the nonsmoking office area.

Table 1 presents the mean and range of concentrations of nicotine, CO, CO_2, the average number of persons per 10 m^2, and the number of cigarettes smoked per hour per 10 m^2 in the three sampling locations.

TABLE 1

COMPARISON OF ETS RELATED AIR QUALITY PARAMETERS: FIELD STUDY 1

	Nicotine (ug/m^3)	CO (ppm)	CO_2 (ppm)	Persons/10m^2	Cig/hr/ 10m^2
FLOOR 11					
Smoking	4.9	2.5	720	0.79	0.36
Permitted	<1.6*-8.0	0.9-5.3	500-900	0.35-1.37	0-0.71
FLOOR 7					
Smoking	<1.6	2.1	680	0.61	NA
Prohibited (recirc)	<1.6-3.0	0.6-3.5	500-900	0.37-0.94	NA
FLOOR 7					
Smoking	75.0	4.3	970	0.94	4.00
Lounge	33.0-210	2.5-6.2	750-1100	0.22-2.11	1.78-5.78

* Level of detection for a 1 hour sample.

Although the two areas in which smoking occurred differed substantially in the number of cigarettes/hr/10 m^2, only nicotine concentrations responded in a similar fashion. The average smoking

intensity (cigarettes/hr/10 m^2) was 10.8 times higher in the smoking designated area than in the smoking-permitted floor. Similarly, the mean nicotine level was 15.6 times higher in the designated smoking lounge, than compared to the smoking-permitted areas.

Smoking was not observed in the nonsmoking areas on floor 7. Nicotine concentrations were below the limit of detection for the one hour sampling periods (<1.6 $\mu g/m^3$) , with one exception. In one of the 10 sampling periods, a nicotine concentration of 3 $\mu g/m^3$ was measured.*

CO and CO_2 concentrations were highest in the smoking lounge, and similar in both the smoking prohibited and smoking permitted office areas.

Study 2

Field study two compared ETS levels in a cafeteria used as a smoking lounge and in an adjacent nonsmoking staff lounge served by the same ventilation system in a four storey building. The floor areas of the smoking lounge and the nonsmoking staff area were 65 m^2 and 46 m^2 respectively.

The ventilation system serving the two study areas was a Variable Air Volume (VAV) system in which outside air was supplied to an air handling unit located in a rooftop penthouse. Outside and return air were mixed by the air handling unit and supplied to the space. On the days of measurement, between 10 and 30% of the return air was being recirculated. Air was ducted from the air handling unit through VAV boxes to slot diffusers in the suspended ceilings of the two study areas. Return air from the space was passively exhausted into a common ceiling plenum through linear slots. A common return fan drew air from the plenum back to the air handling unit. By using the ceiling as the return air plenum, air exhausted from the smoking lounge may be recirculated to other locations served by the same air handling unit, such as the staff lounge.

*In view of the fact that nine of the ten samples were below the level of detection (1.6 $\mu g/m^3$), the single detected value may be questionable, possibly due to an unobserved smoker or analytical error.

Table 2 shows the mean and ranges of ETS related contaminants in the smoking lounge and nonsmoking staffrooms.

TABLE 2

COMPARISON OF ETS RELATED AIR QUALITY PARAMETERS: FIELD STUDY 2

	Nicotine (ug/m^3)	RSP (ug/m^3)	CO_2 (ppm)	# of Cigs Smoked*
Cafeteria/ Smoking Lounge	5.8 3.8-7.2	60.4 27-82	500 400-600	7.1 2-15
Nonsmoking Lounge (recirc)	0.6 <0.4**-0.8	20.8 17-26	403 350-450	-- --
Outdoors	-- --	15.0 13-16	358 300-400	-- --

* The number of cigarettes being smoked at the time of instantaneous measurements was recorded and a mean calculated.
**Level of detection for a 4 hour sample.

Mean nicotine concentration in the smoking lounge was 5.8 $\mu g/m^3$ Nicotine was measured at concentrations just above the detection limit (< 0.4 $\mu g/m^3$) in 3 of the 4 samples taken in the nonsmoking staff lounge, suggesting a low level of recirculation.

RSP concentrations were 2.9 times higher in the smoking lounge than in the nonsmoking areas. CO_2 concentrations were 1.2 times higher.

Study 3

In the third study, ETS related parameters were measured in two adjacent buildings, which contained a mixture of open-area offices, private offices and public waiting/service areas.

Building A was a sealed, mechanically ventilated four storey office building with two levels of underground parking. The building was served by a central ventilation system. Outside air was drawn into an air handling unit located in a basement mechanical room, mixed with return air and supplied to each floor through ceiling diffusers. Return air was drawn from the ceiling plenum back to the basement air handling unit. The amount of air recirculated by the system varied from 0 to 80%, depending on

outdoor temperatures. At the time of survey, approximately 30 to 50% of the return air was recirculated.

Smoking was prohibited in all areas of Building A, except for a smoking section in the fourth floor cafeteria, which was not separately ventilated from the rest of the building or physically separated from the nonsmoking section. Therefore, return air from the smoking area could be recirculated throughout the building.

Building B was a 12-storey unsealed office building without mechanical ventilation. Most areas were therefore passively ventilated by building leakage. The building was heated by a hot water radiant system. Consequently, there was no mixing of air from different floors or offices. Smoking was prohibited in all areas of the building except in the smoking section of a basement cafeteria. No air from the cafeteria could be recirculated elsewhere in the building.

Table 3 summarizes the measurement results. As there were no perceptible differences between the measured concentrations in cafeterias in Buildings A and B, either for smoking and nonsmoking areas, their data has been merged.

TABLE 3

COMPARISON OF ETS RELATED AIR QUALITY PARAMETERS: FIELD STUDY 3

	Nicotine (ug/m^3)	RSP* (ug/m^3)	CO (ppm)	CO_2 (ppm)	Pers/ $10m^2$	Cigs/ $hr/10m^2$
Cafeteria Smoking Sec. (A & B comb)	14.0 <1.6-43.7	70 23-129	3.9 1.1-11.4	690 450-1000	1.8 .8-3.4	1.2 .5-1.7
Cafeteria Nonsmok Sec. Areas (A & B comb)	6.2 <1.6-10.9	32 15-57	2.6 1.2-4.5	560 400-700	1.7 .8-2.5	NA NA
Nonsmoking Offices Bldg A (recirc)	<0.8 <0.4-1.0	6 4-11	1.8 1.3-2.3	490 400-580	0.73 .3-1.9	NA NA
Nonsmoking Offices Bldg B (no recirc)	-- --	7 6-8	1.35 1.3-1.4	450 400-500	0.9 .5-1.3	NA NA

* Mean outdoor RSP's were 10 ug/m3.

There was a higher occupant density in the cafeterias than in the nonsmoking office areas. However, the number of individuals per 10 m^2 in the smoking and nonsmoking sections of the cafeterias were approximately the same. Measured levels of all four air quality parameters were higher in the smoking sections than in the nonsmoking sections of the cafeterias. The decrease in RSP and nicotine concentrations between the smoking and nonsmoking areas of the cafeterias illustrates a rapid dilution of ETS.

Eight nicotine samples were collected in the nonsmoking offices of Building A. Measurable levels of nicotine were found in 2 of the 8 samples, indicating a low level of ETS infiltration.

DISCUSSION

The results from the three field studies suggest that ETS contributes little to indoor CO_2 levels. Differences in CO_2 concentrations between the smoking-permitted, prohibited and designated smoking areas were small when compared with the observed differences in smoking intensity and nicotine levels. The sample sites with highest CO_2 levels in the four studies were those areas with the higher person densities.

Indoor CO concentrations increased with smoking but did not closely follow smoking intensity or nicotine concentrations. Other indoor and outdoor sources must also contribute to CO levels in buildings, as indicated by the background levels measured in areas which do not receive air recirculated from smoking lounges.

RSP concentrations were substantially higher in the smoking than nonsmoking areas. There were few differences between RSP concentrations measured in nonsmoking areas that received ,or did not receive, air recirculated from the smoking lounge. This finding suggests that recirculation of ETS can not be detected by elevated RSP concentrations.

Of the four substances measured, nicotine showed the strongest association with smoking. There are few, if any, significant sources of nicotine in the non-industrial indoor environment other than smoking. The results of the field studies clearly indicate that nicotine is the most accurate marker of the presence of ETS.

Nicotine was detected in six of 21 samples taken in nonsmoking areas that received recirculated air. In those cases where nicotine was detected, concentrations were more than 10 times lower than in the smoking lounge. These measurements indicate that ETS

components are substantially diluted as they are recirculated from smoking designated to smoking prohibited work areas. Of course what is "substantial" dilution is to some extent subjective. To give meaning to such trace values, it has been demonstrated that the exposure of an office worker to recirculated nicotine is at, or below, 1 $\mu g/m^3$ for one hour. Giving a breathing rate of 0.48 m^3/hr for the level of activity required for normal office work (4), an office worker would breath air containing 0.48 µg of nicotine in one hour. This quantity is approximately equivalent to 1/1800 of nicotine inhaled by actively smoking one cigarette (900 µg/cigarette. (5)

Overall, based on the results of the field studies, it appears that the provision of designated smoking areas in the four buildings has acted to effectively reduce ETS constituent levels in nonsmoking offices, even when the designated smoking areas are not separately ventilated.

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